https://dx.doi.org/10.22161/ijaers/3.10.29 *ISSN: 2349-6495(P) | 2456-1908(O)*

The Effect of a Distance from Water Treatment Plant on Residual Chlorine

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***Abstract*—*Disinfection with chlorine is very popular in water and wastewater treatment because of its low cost, ability to form a residual, and its effectiveness at low concentrations. Chlorinated drinking water's chief benefit is the protection of public health through the control of waterborne diseases. It plays a paramount role in controlling pathogens in water that cause human illness, as evidenced by the virtual absence of waterborne diseases such as typhoid and cholera in developed countries. But, there are many factors that can affect the chlorine in the water such as distance. From the Chick's Law, the concentration of the chlorine residual in water will decrease when the distance increased. By collecting samples and data's from water treatment plant (Alzarqe Kufa) and its networks by determining the sampling points and the distance from water treatment plant, compare the data's or levels of chlorine from the network with the levels of chlorine at plant, and check if the residual chlorine in the water supply are following the standard by Iraqi Water Association. From the results, we can improve the quality of the water supply to user to protect the public health through the control of waterborne diseases.*

***Keywords*— Disinfection, Water treatment plant, Public health, Residual chlorine.**

I. INTRODUCTION

Disinfecting drinking water is considered important for the maintenance of water quality in transmission and distribution systems. Treated water is disinfected before it enters the transmission system [1]. The organisms in water, which it may be necessary to kill by disinfection include bacteria, bacterial spores, viruses, protozoa and protozoa cysts, worms and larvae.

Chlorinated drinking water's chief benefit is the protection of public health through the control of waterborne diseases. It plays a paramount role in controlling pathogens in water that cause human illness, as evidenced by the virtual absence of waterborne diseases such as typhoid and cholera in developed countries [2].

Untreated or inadequately treated drinking water supplies remain the greatest threat to public health, especially in developing countries, where nearly half the population drinks contaminated water. In these countries, diseases such as cholera, typhoid and chronic dysentery are endemic and kill young and old alike.

Because organisms' contamination of water can be expected in the transmission and distribution system, a detectable disinfectant residual should remain in the water so that the potential for waterborne disease and biofilm growth will be minimized [3].

Despite the fact the disinfection process may seem simple, it is actually a quite complicated process. Chlorination in water treatment systems is a fairly complex science which requires knowledge of the plant's effluent characteristics. When free chlorine is added to the water, it takes on various forms depending on the pH of the wastewater [4]. It is important to understand the forms of chlorine, which are present because each has a different disinfecting capability. The acid form, HOCL, is a much stronger disinfectant than the hypochlorite ion, OCL^-.

Disinfection can be attained by means of physical or chemical disinfectants. The efficacy of disinfection depends on numerous factors: the type of disinfectant used; the amount applied and the time for which it is applied; the type and numbers of organisms present; and the physical and chemical characteristics of the water [5].

II. PROBLEM STATEMENTS

Many of the most common diseases found in the traumatized communities after a disaster or emergency are related to drinking contaminated water. The contaminated can be from micro-organisms like hepatitis, cholera and diarrhea or natural and man-made chemicals like arsenic and mercury. People who live in the same place all their lives and regularly drink contaminated water may develop some resistance to the contaminants and suffer little or no health problems [6]. Communities affected by an emergency, however, one of there emergencies that effects on people and force them to move to new places where the water quality is different from what they usually drink and for which they have no immunity.

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III. OBJECTIVES OF THE STUDY

3.1 General objective

The overall objective of this study was to determine the effects of distance from water treatment plant on residual chlorine in Alzarqe Kufa Town.

3.2 Specific objectives

i. To calculate the effect of distance from water treatment plant on residual chlorine.
ii. Develop knowledge on the effect of distance on the chlorine residual.
iii. Propose the strategies on dosing of chlorine.

IV. SCOPE OF WORK

The scope of work focuses on collecting samples and data's from water treatment plant (Alzarqe water treatment plant Kufa) and it networks by determine the sampling points and the distance from water treatment plant. After that, compares was made the data or levels of chlorine from the network with the levels of chlorine at the plant.

V. JUSTIFICATION OF THE RESEARCH

The graph (Figure 1) shown depicts the chlorine residual as a function of increasing chlorine dosage with descriptions of each zone given below [7].

i. Zone I: Chlorine is reduced to chlorides.
ii. Zone II: Chloramines are formed.
iii. Zone III: Chloramines are broken down and converted to nitrogen gas which leaves the system (Breakpoint).
iv. Zone IV: Free residual.

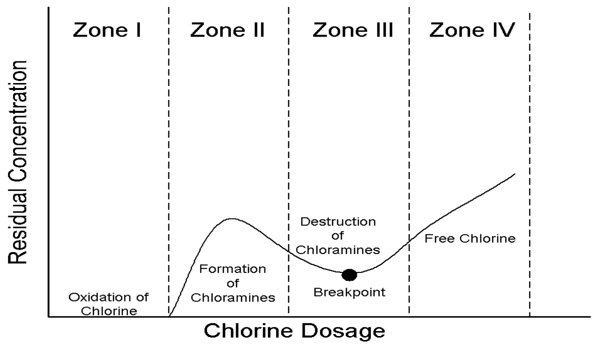

Fig. 1: Chlorine Breakpoint

Therefore, it is very important to understand the amount and type of chlorine that must be added to overcome the difficulties in the strength of the disinfectant which results from the water's characteristics. So with this project, we can improve the quality of the water supply to users. We can develop knowledge on the effect of distance on the chlorine residual. When we know the result, the strategies on dosing of chlorine could be developed.

VI. LITERATURE REVIEW

6.1 Theoretical Review

At the beginning of the country, Harriet Chick postulated that for a given disinfection and concentration, the death of microorganisms follows first-order kinetic with respect to time. Chick's Law can also apply to express the decrease in titer of microbial population due to other inactivating factors in an unfavorable environment [8].

$$-\frac{dX}{dt} = kX \qquad \text{Equation 1.1}$$

X = Concentration of living microorganisms at time, t
k = first order decay rate (1/time)

$$X = X_0 e^{-kt} \qquad \text{Equation 1.1}$$

Or

$$\ln\frac{X}{X_0} = -kt \qquad \text{Equation 1.1}$$

X = Concentration of living microorganisms at time, t (number/unit volume)
X_0 = initial concentration of living microorganisms (number/unit volume)
k = decay rate (1/time)
t = time

When chlorine is used as a disinfectant agent in a piped distribution system, it is desirable to maintain free chlorine residual of 0.2 - 0.5 mg/L throughout, to reduce the risk of microbial re-growth and the health risk of recontamination. In an emergency, for example, in refugee camps during the outbreaks of potentially waterborne disease, or when fecal contamination of a water supply is detected, the concentration of free chlorine should be increased to greater than 0.5 mg/L throughout the system. High levels of turbidity can protect microorganisms from the effects of disinfection agents, simulated the growth bacteria, and give rise to a significant chlorine demand. Chlorine can be easily monitored and controlled as a drinking water disinfectant, and regular, frequent monitoring is recommended wherever chlorination is practiced. So, along the piped system when the distances are increased, the chlorine residual will decrease because the chlorine will react with the microorganisms along the piped line [9].

6.1.1 Disinfection Kinetics

When a single unit of microorganisms is exposed to a single unit of disinfectant, the reduction in microorganisms follows a first-order reaction.

$dN/dt=-kN$ $\qquad N=N_0e^{-kt}$

This equation is known as Chick's Law:-
N = number of microorganism (N_0 is initial number)
k = disinfection constant

https://dx.doi.org/10.22161/ijaers/3.10.29 ISSN: 2349-6495(P) | 2456-1908(O)

t = contact time

6.2 Chlorine Residual

Chlorine is the eleventh most abundant element in nature, often in chlorides. It is naturally present in the sea (sodium chloride), rivers and plants, as well as in salt deposits formed thousands of years ago by the evaporation of inland seas. Connected to certain natural compounds, chlorine is a natural element in our environment, just as essential as carbon, hydrogen and oxygen. The human skin, teeth and even blood contain natural compounds based on chlorine. It plays an important role in the human immune system whereby, thanks to a special enzyme, the white cells of the human body create sodium hypochlorite (active chlorine) to kill threatening bacteria. In a certain way, it is as if the body invented disinfection by chlorine before the scientists did [9].

Due to its low cost, stability, and effectiveness, chlorine are widely used for disinfecting water. Generally, a free chlorine residual in excess of 0.2 mg/l – 0.5 mg/l must be maintained in the distribution system, thus reducing the likelihood of further contamination. However, chlorine concentration decreases with time due to consumption.

[10] pointed out that reaction of chlorine on the scales coating the inner pipe surfaces is the main reason for the loss of such disinfectant within distribution networks. These reactions cause a decrease in the chlorine content in the water. [11] observed that there was a rapid decrease in both free and total chlorine residual in the water in the distribution system, as residence time increases while travelling from the treatment plant. [12] observed that chlorine residual loss averaged about 40% after 24 h of disinfecting of new pipes at high chlorine concentrations, such as during mains disinfection. The studies [9] showed that free and total chlorine residuals decrease rapidly as distance from the treatment plant increases and free chlorine residuals disappear in the peripheral sections of the distribution system. Moreover, chlorine decay rates increase with an increase in water temperature.

6.3 Factors of decrease chlorine concentration

6.3.1 CT

This stands for the contact time between disinfectant and microorganism and the concentration of disinfectant. CT is used to calculate how much disinfectant is required to adequately disinfect water.

C= to the final residual concentration of a particular chemical disinfectant in mg/L.

T= to the minimum contact time (minutes) of material that is disinfected with the disinfectant.

Unit = mg-min/L.

CT = disinfectant concentration x contact time

= C mg/L x T minutes

When a particular disinfectant is added to water, it does not only react with pathogenic microorganisms, but also with other impurities, such as soluble metals, particles of organic matter and other microorganisms. The utilization of a disinfectant for reactions with these substances make up the disinfection demand of the water. The disinfection demand must first be satisfied, before a residual disinfectant concentration can be established. The disinfectant concentration that has to be added to water is made up by the sum of the disinfection demand and the residual disinfectant concentration [7].

Usually a dose of 12-20 mg/L chlorine is required to result in a free chlorine residual concentration of 6-8 mg/L. The time required to deactivate a particular microorganism decreases when the applied disinfectant concentration (mg/L) is increased. Laboratory tests are conducted, to find out which contact time is most effective [6].

6.3.2 The type of microorganism

Disinfectants can effectively kill pathogenic microorganisms (bacteria, viruses and parasites). Some microorganisms can be resistant. E. coli bacteria, for example, are more resistant to disinfectants than other bacteria and are therefore used as indicator organisms. Several viruses are even more resistant than E. coli. The absence of E. coli bacteria does not mean that the water is safe. Protozoan parasites like Cryptosporidium and Giardia are very resistant to chlorine [5].

6.3.3 The age of the microorganism

The affectivity of a particular disinfectant also depends upon the age of the microorganism. Young bacteria are easier to kill than older bacteria. When bacteria grow older, they develop a polysaccharide shell over their cell wall, which makes them more resistant to disinfectants. When 2,0 mg/L chlorine is used, the required contact time to deactivate bacteria that are 10 days old is 30 minutes. For bacteria of the same species and of the age of 1 day 1 minute, contact time is sufficient. Bacterial spores can be very resistant. Most disinfectants are not effective against bacterial spores.

6.3.4 Water that requires treatment

The nature of the water that requires treatment has its influence on the disinfection. Materials in the water, for example iron, manganese, hydrogen sulphide and nitrates often react with a disinfectant, which disturbs disinfection. Turbidity of the water also reduces the affectivity of disinfection. Microorganisms are protected against disinfection by turbidity.

6.3.5 Temperature

The temperature also influences the affectivity of disinfection. Increasing temperatures usually increase the speed of reactions and of disinfection. Increasing

https://dx.doi.org/10.22161/ijaers/3.10.29 ISSN: 2349-6495(P) | 2456-1908(O)

temperatures can also decrease disinfection, because the disinfectant falls apart or is violated.

6.3.6 Pipe age

While flowing through pipes, the chlorine concentration decreases for different reasons. Reaction with the pipe material itself and the reaction with both the biofilm and tubercles formed on the pipe wall are known as pipe wall demand, which may vary with pipe parameters.

VII. METHODOLOGY

7.1 Preparation of samples

Water samples were prepared by collecting the water from houses along the study area. For every 1 km, water sample from each house will be collected and the distance from water treatment plant was recorded. Distance will be measured by using the meter of the motorcycle. The sample must be collected as fast as possible. Do not store the samples because chlorine in aqueous solution is not stable, and the chlorine content of samples or solutions, particularly weak solutions, will decrease rapidly. Exposure to sunlight or other strong light or agitation will accelerate the reduction of chlorine. Therefore, samples must be collected as fast as possible and start the test on chlorine residual immediately after sampling. Before collecting the water samples, the bottle used in sampling must be clean to prevent any chlorine reaction in the bottle during sample collection.

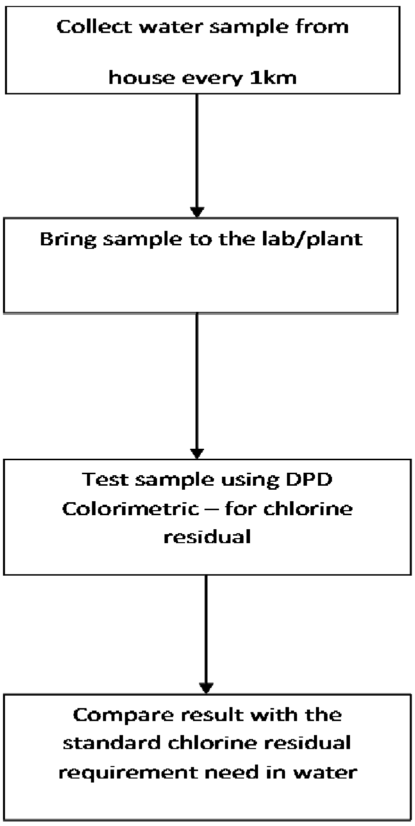

Fig. 2: Preparation Of Samples

7.2 Analysis procedures of samples

i. Using DPD Colorimeter Program 9, use the 24 mm vial with 10 mL of sample from the zero procedure.
ii. Take one Chlorine Total DPD Powder Pack, tap down gently and tear open in the direction of the text. Add the contents to the sample vial.
iii. Screw the cap onto the vial tightly and swirl vigorously to dissolve the powder. A pink color will develop if chlorine is present.
iv. Immediately, place the prepared sample into the sample chamber. Cover with the vial cover.
v. Press meas key for sample measurement.
vi. The instrument will begin a two-minute countdown period, then the result will appear in the display as mg/L (or ppm) total chlorine residual.
vii. If the display flashes “overrng”, it is due to high chlorine levels. Dilute a fresh sample and repeat the test [13].

VIII. RESULTS AND DISCUSSION

8.1 From plant to direction 1 (D1)

17 May 2015 (Time : 10.00 am – 12.00 pm)

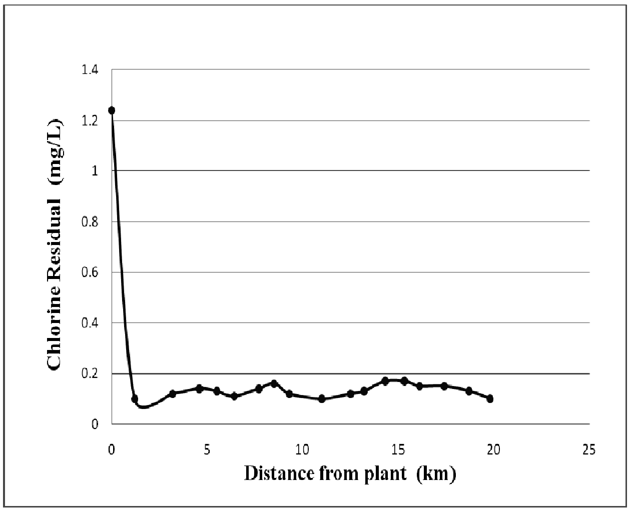

Fig. 3: Graph Chlorine Residual versus Distance for (D1)

From Figure 3 the result shows the free chlorine test leaving the treatment plant at 17 May 2015 was high at 1.24 mg/L, which is higher than the WHO Standard. The result also shows that the free chlorine residual dropped than the free chlorine residue concentration when leaving Alzarqe water treatment plant Kufa. Since the distance between the treatment plant and the sampling last point is quite far (about 20km), this result confirms that the chlorination process in Alzarqe water treatment plant was sufficient of contact time and was not enough chlorine to maintain the chlorine concentration. Also the Figure 3 shows that the line is not smooth as the theory. This is

because the other factors like contact time, temperature and storage time before doing the chlorine residual test.

8.2 From plant to direction 2 (D2)

20 May 2015 (Tim:: 10.00 am – 12.00 pm)

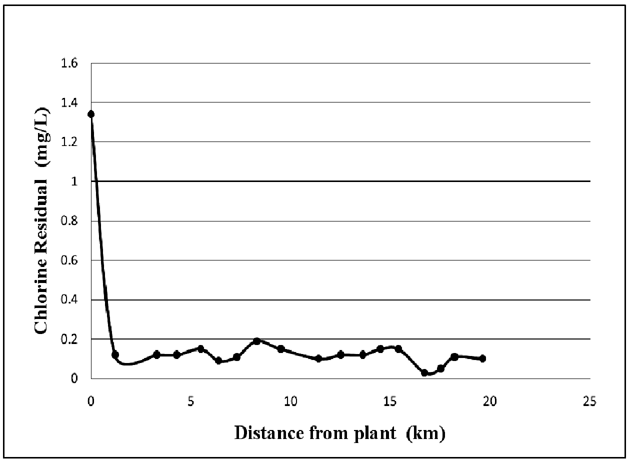

Fig. 4: Graph Chlorine Residual versus Distance for (D2)

From Figure 4 the result shows the free chlorine test leaving the treatment plant at 20 May 2015was high at 1.34 mg/L, which is higher than the WHO Standard. The result also shows that the free chlorine residual dropped when leaving the Alzarqe water treatment plant. Since the distance between the treatment plant and the last sampling point is quite far (about 20km), this result confirms that the chlorination process in the Alzarqe water treatment plant was sufficient of contact time and was not enough chlorine to maintain the chlorine concentration. The Figure 4 shows that the line is not smooth as the theory. This is because the other factors like temperature and storage time before doing the chlorine residual test.

8.3 From plant to direction 3 (D3)

18 May 2015 (Time : 10.00 am – 12.00 pm)

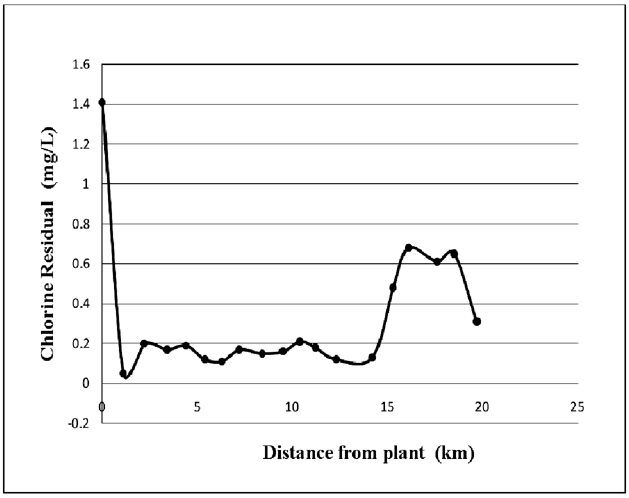

Fig. 5: Graph Chlorine Residual versus Distance for (D3)

From Figure 5 the result shows the free chlorine test leaving the treatment plant on 18 May 2015 was high at 1.24 mg/L, which is higher than the WHO Standard. The result also shows that the free chlorine residual dropped compared to the free chlorine residue concentration when leaving Alzarqe water treatment plant. Since the distance between the treatment plant and the sampling last point is quite far (about 20km), this result confirmed that the chlorination process in Alzarqe water treatment plant was sufficient of contact time and was not enough to maintain the chlorine concentration (0.2 to 0.5 mg/l). The Figure 5 shows that the line is not smooth as the theory. This is because the other factors like temperature and storage time before doing the chlorine residual test. An increase in chlorine residual after 15 km from the water treatment plant suggested that there was as function of chloramine.

8.4 From plant to direction 4 (D4)

21 May 2015 (Time : 10.00 am – 12.00 pm)

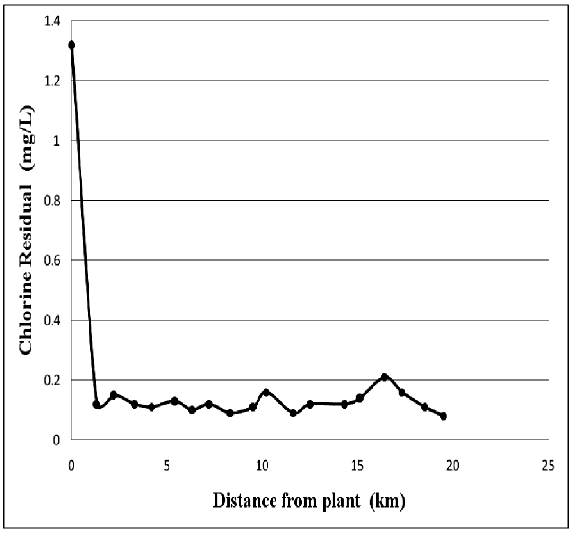

Fig. 6: Graph Chlorine Residual versus Distance for (D4)

From Figure 6 the result shows the free chlorine test leaving the treatment plant on 21 May 2015 was high at 1.24 mg/L, which is higher than the WHO Standards. The result also shows that the free chlorine residual dropped below the free chlorine residue concentration when leaving Alzarqe water treatment plant. Since the distance between the treatment plant and the last sampling point is quite far (about 20km), this result confirmed that the chlorination process in Alzarqe water treatment plant was sufficient of contact time and was not enough to maintain the chlorine concentration. The Figure 6 shows that the line is not smooth as the theory. This is because the other factors like temperature and storage time before doing the chlorine residual test.

8.5 From plant to direction 5 (D5)

19 May 2015 (Time : 10.00 am – 12.00 pm)

https://dx.doi.org/10.22161/ijaers/3.10.29 *ISSN: 2349-6495(P) | 2456-1908(O)*

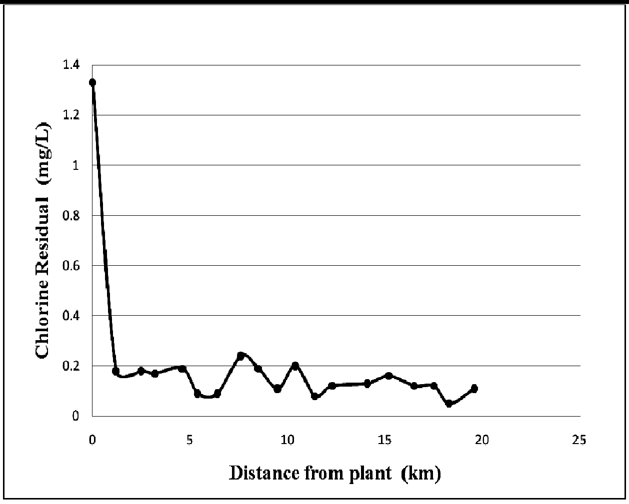

Fig. 7: Graph Chlorine Residual versus Distance for (D5)

From Figure 7 the result shows the free chlorine test leaving the treatment plant on 19 May 2015 was high at 1.24 mg/L, which is higher than the WHO Standards. The result also shows that the free chlorine residual dropped below the free chlorine residue concentration when leaving Alzarqe water treatment plant. Since the distance between the treatment plant and the last sampling point is quite far (about 20km), this result confirmed that the chlorination process in Alzarqe water treatment plant was sufficient of contact time and was not enough to maintain the chlorine concentration. The Figure 7 shows that the line is not smooth as the theory. This is because the other factors like temperature and storage time before doing the chlorine residual test.

8.6 From plant to direction 6 (D6)

22 May 2015 (Time : 10.00 am – 12.00 pm)

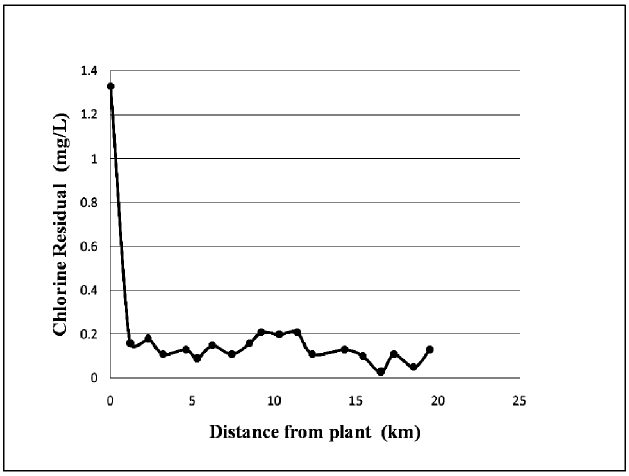

Fig. 8: Graph Chlorine Residual versus Distance for (D6)

From Figure 8 the result shows the free chlorine test leaving the treatment plant on 22 May 2015 was high at 1.24 mg/L, which is higher than the WHO Standards. The result also shows that the free chlorine residual dropped below the free chlorine residue concentration when leaving Alzarqe water treatment plant. Since the distance between the treatment plant and the sampling last point is quite far (about 20km), this result confirmed that the chlorination process in Alzarqe water treatment plant was sufficient of contact time and was not enough to maintain the chlorine concentration. The Figure 8 shows that the line is not smooth as the theory. This is because the other factors like temperature and storage time before doing the chlorine residual test.

IX. CONCLUSION

Disinfection with chlorine is very popular in water and wastewater treatment because of its low cost, ability to form a residual, and its effectiveness at low concentrations. When the distance increased, chlorine residual in water will decrease. So to maintain the chlorine concentration, the additional points for chlorine need to add at certain distance when the chlorine became low than requirement (0.2 – 0.5 mg/L). So to add the additional points, we need to know the correct distance before we can placed the additional points, to make sure that we placed at correct point. With this we can improved the quality of water supply to user and can protect the public health through the control of waterborne diseases.

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